SIT-HEP/TM-2

hrp-ph/0102040

Defect-mediated electroweak baryogenesis and hierarchy

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Abstract

We consider the scenario of electroweak baryogenesis mediated by cosmological defects, in models for dynamical supersymmetry breaking and extra dimensions. When the electroweak breaking scale is enhanced in the defect, it protects the baryon charge from sphaleron wash-out throughout the evolution of the Universe, until baryon number violating processes become harmless. We also consider the case where the sphaleron interaction is activated in the false vacuum. The mechanism is general and effective in any models for electroweak symmetry breaking, if cosmological defects are formed in the sector that is responsible for hierarchy.

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1 Introduction

Contrary to a naive cosmological expectation, all evidences suggest that the Universe contains an abundance of matter over antimatter. Electroweak baryogenesis is an attractive idea in which testable physics, present in the standard model of electroweak interactions and its modest extensions, is responsible for this fundamental cosmological datum. One may take the previous negative results as indication that the asymmetry in the baryon number was not created at the electroweak epoch, but rather related to the physics of $B-L$ violation and neutrino masses. To stick to electroweak baryogenesis one can consider extensions of the particle content of the model to get stronger electroweak phase transition. In general scenario for electroweak baryogenesis requires the co-existence of regions of large and small $< H/T >$, where H denotes the Higgs field in the standard model. At small $< H/T >$, sphalerons are unsuppressed and mediate baryon number violation while large $< H/T >$ is needed to store the created baryon number. Below the critical temperature T_c^{EW} of the electroweak phase transition, $< H/T >$ grows until sphalerons are shut-off. For electroweak baryogenesis to be possible, one needs some specific regions where $< H >$ is displaced from the equilibrium value.

The idea we examine in this paper is that this can happen along topological defects left over from some other cosmological phase transitions that took place before the electroweak phase transition[1].

If the electroweak symmetry breaking scale is enhanced in some regions around cosmological defects, sphalerons could be suppressed in such regions while they would be effective in the bulk of space. The motion of the defect network, in a similar way as the motion of bubble walls in the usual strongly first order phase transition scenario, will leave a net baryon number behind the moving surface and then the baryon asymmetry will be kept in the sphaleron-suppressed regions in the defects. Then the defects protect the baryon charge from sphaleron wash-out throughout the evolution of the Universe, until baryon number violating processes become harmless. In section 2, we will point out that this idea works in supersymmetric extensions of the standard model when the supersymmetry breaking scale is raised around the defects. The defects should be formed before electroweak phase transition and decay after baryon number processes become harmless.

Supersymmetric extensions are one of the best-motivated of the particle physics theories beyond the standard model. Supersymmetry solves the gauge hierarchy problem, couples gauge theory to gravity, and may generate the gauge coupling unification. However, the present state of the Universe is obviously not supersymmetric, and thus supersymmetry must be broken in Nature at some scale higher than $O(TeV)$. Spontaneous supersymmetry breaking entails adding to the supersymmetric version of the extended standard model some new fields acting as a supersymmetry breaking sector. There are many ways in which supersymmetry breaking can be communicated from the breaking sector to the visible sector. The defects can break supersymmetry locally and only at a short period of cosmological evolution of the Universe.

In section 3 we consider a model for extra dimension. We find that sphaleron mediated electroweak baryogenesis at lower temperature is possible when the radion is stabilized by the Goldberger-Wise mechanism[2].

2 Toy model 1 (GMSSB)

One popular scenario of supersymmetry breaking is the so-called "hidden sector" supersymmetry breaking in supergravity[3]. In hidden sector models, supersymmetry is broken in the hidden sector by some mechanisms, such as the Polonyi model[4], gaugino condensation[5], or the O'Rafeartaigh model[6], and the effects of the supersymmetry breaking are mediated to the fields in the supersymmetric standard model only by interactions suppressed by the cut-off scale.

We also know that the supersymmetry breaking can be mediated by gauge interactions. The gauge mediation of supersymmetry breaking is an alternative mechanism which can ensure the degeneracy of squark masses and therefore suppresses the dangerous FCNC effects.

The main motivation for these models is to realize the stable hierarchy between the fundamental scale and the electroweak scale. In this case, the quadratic divergence in the Higgs boson mass parameter coming from a top quark radiative correction is cancelled by that coming from a scalar top. Including supersymmetry breaking at scale m_{SUSY}, the resulting divergence is logarithmic. The Higgs mass is reliably computed in the effective theory, and is not dominated by unknown physics at the cutoff. To be more precise, one can say that the stability of the hierarchy is due to the existence of supersymmetry at higher energy scale, while the hierarchy is produced by the dynamical breaking of supersymmetry or large suppression factor from the fundamental scale. One can also find some alternatives of these mechanisms for supersymmetry breaking in the light of M theory, large extra dimensions and brane worlds.

In this section we explore the possibility of obtaining the baryon asymmetry of the Universe by using a toy model for the gauge mediated supersymmetry breaking. Here we do not examine the mass spectrum of any concrete example, but simply put the assumption that the electroweak scale is intimately related to the scales for supersymmetry breaking in the breaking sector or in the mediation sector, which we think reasonable for our purposes.

Let us consider the simplest version of the gauge mediated model for supersymmetry breaking(GMSSB). The messenger sector can be described by the superpotential

$$W_M = \frac{1}{3}\lambda S^3 + \kappa S \Phi^+ \Phi^- + \kappa_q S q \overline{q} + \kappa_l S l \overline{l}, \tag{2.1}$$

where S is a singlet superfield, and $\Phi^{\pm}$ are charged under a $U(1)$ associated with the supersymmetry breaking sector and are singlets under the standard model gauge group. The superfield q transforms as a $(3,1,\frac{1}{3})$ under the standard model, while l transforms as $(1,2,-\frac{1}{2})$. The scalar component of $\Phi^{\pm}$ acquires negative supersymmetry breaking mass squared due to its interaction with the supersymmetry breaking sector, which is usually accomplished by the $U(1)$ interaction. It is easy to see that S and F_S can acquire vacuum expectation values $< S >$ and $< F_S >$ when $\Phi^{\pm}$ acquire negative supersymmetry breaking mass squared. These effects feed down to the MSSM sector through loop corrections. The soft terms are calculated to depend on the parameter $< F_S/S >$ in the messenger sector.

What we will concern is the situation when the typical scale for the soft supersymmetry breaking parameter $< F_S/S >$ is raised in the defect core, but is not affected in the bulk of space. This can be realized in a simplest way if the dynamical supersymmetry breaking sector or the messenger sector develop a cosmological defect. In this case the excessive breaking of supersymmetry is realized in the defect core which may be at the maximum of the potential. [2]

[2]Moreover, the defect sector is not necessarily identical to the dynamical supersymmetry breaking

In general, the electroweak scale is intimately related to the soft breaking parameters which can be raised in the "local" region in the defect core. When $T_c > T > T_{EW}$, baryon asymmetry is produced by the sphaleron interactions around the defect, then is trapped in the defects. Defects are able to trap the baryon from the time of the symmetry breaking phase transition in the core (at $T = T_c$) till the Universe cools down to $T = T_{EW}$. Then the defects release the baryon number and finally disappear at $T = T_d$.

Here the mechanism for baryon asymmetry generation is almost the same as the electroweak baryogenesis. Historically, the ways in which baryons may be produced as a bubble wall, or phase boundary, sweeps through space, have been separated into two categories. One is the local baryogenesis in which baryons are produced when the baryon number violating processes and the CP violating processes occur together near the bubble walls, and the other is the nonlocal baryogenesis in which particles undergo CP violating interactions with the bubble wall and carry an asymmetry in a quantum number other than the baryon number into the unbroken phase region away from the wall. Baryons are then produced as baryon number violating processes convert the existing asymmetry into one in the baryon number. In general, both local and nonlocal baryogenesis will occur and the baryon number asymmetry of the Universe will be the sum of that generated by the two coexisting processes. When the speed of the defect boundary is greater than the sound speed in the plasma, local baryogenesis dominates. In other cases, nonlocal baryogenesis is usually more efficient.

We first consider electroweak baryogenesis mediated by a wall-like defect, then examine a string-like defect.

Cosmological Domain walls

It is well known that whenever the Universe undergoes a phase transition associated with the spontaneous symmetry breaking, domain walls will inevitably form. In most cases the domain walls are dangerous for the standard evolution of the universe. First, let us review how to estimate the constraint to safely remove the cosmological walls. The

sector or the messenger sector. The supersymmetry breaking in the defect sector can vanish in the true vacuum, but should be large in the defect core to realize the co-existence of the regions of large and small $< H/T >$. Since the defect sector is not necessarily required to induce the soft terms in the MSSM in the true vacuum, there are no complexities related to the dynamical breaking of supersymmetry at the global minimum, the constraint on the CP breaking parameter, etc.

crudest estimate we can make is to insist that the walls are removed before they dominate over the radiation energy density in the Universe. When the discrete symmetry is broken by gravitational interactions, the symmetry is an approximate discrete symmetry. The degeneracy is broken and the energy difference $\epsilon \neq 0$ appears. Regions of higher density vacuum tend to shrink, the corresponding force per unit area of the wall is $\sim \epsilon$. The energy difference ϵ becomes dynamically important when this force becomes comparable to the force of the tension $f \sim \sigma/R_w$, where σ is the surface energy density of the wall and R_w denotes the typical scale for the wall distance. For walls to disappear, this has to happen before the walls dominate the Universe. On the other hand, the domain wall network is not a static system. In general, the initial shape of the walls right after the phase transition is determined by the random variation of the scalar VEV. One expects the walls to be very irregular, random surfaces with a typical curvature radius, which is determined by the correlation length of the scalar field. To characterize the system of domain walls, one can use a simulation[10]. The system will be dominated by one large (infinite size) wall network and some finite closed walls (cells) when they form. The isolated closed walls smaller than the horizon will shrink and disappear soon after the phase transition. Since the walls smaller than the horizon size will efficiently disappear so that only walls at the horizon size will remain, their typical curvature scale will be the horizon size, $R \sim t \sim M_p/g_*^{\frac{1}{2}}T^2$. Since the energy density of the wall ρ_w is about

$$\rho_w \sim \frac{\sigma}{R}, \tag{2.2}$$

and the radiation energy density ρ_r is

$$\rho_r \sim g_* T^4, \tag{2.3}$$

one sees that the wall dominates the evolution below a temperature T_w

$$T_w \sim \left(\frac{\sigma}{g_*^{1/2} M_p}\right)^{\frac{1}{2}}. \tag{2.4}$$

To prevent the wall domination, one requires the pressure to have become dominant before this epoch,

$$\epsilon > \frac{\sigma}{R_{wd}} \sim \frac{\sigma^2}{M_p^2}. \tag{2.5}$$

Here R_{wd} denotes the horizon size at the wall domination. A pressure of this magnitude would be produced by higher dimensional operators which explicitly break the discrete symmetry[11].

In our case, the requirement that the walls decay after electroweak symmetry breaking imposes the upper bound on σ as $\sigma < (10^8 GeV)^3$, which excludes the hidden (M_p suppressed) sector for the defect.

The criterion (2.5) seems appropriate, if the scale of the wall is higher than $(10^5 GeV)^3$. For the walls below this scale ($\sigma \leq (10^5 GeV)^3$), there should be further constraints coming from primordial nucleosynthesis. Since the time associated with the collapsing temperature T_w is $t_w \sim M_p^2/g_*^{\frac{1}{2}}\sigma \sim 10^8 \left(\frac{(10^2 GeV)^3}{\sigma}\right)$sec, the walls $\sigma \leq (10^5 GeV)^3$ will decay after nucleosynthesis[12]. If the walls are not hidden and can decay into the standard model particles, the entropy produced when walls collapse will violate the phenomenological bounds for nucleosynthesis. On the other hand, this simple bound from the nucleosynthesis is not effective for the walls which cannot decay into standard model particles. The walls such as soft domain walls[13], the succeeding story should strongly depend on the details of the hidden components and their interactions. These walls can decay late to contribute to the large scale structure formation.

Of course, the condition for the cosmological domain wall not to dominate the Universe (2.5) should also be changed if the wall velocity is lower than the speed of the light and then the Universe contains walls more than one. This implies that the condition to evade the wall domination becomes $\epsilon > (\sigma^2/M_p^2) \times x$, where the constant x is determined by R_w as $x \simeq M_p/(R_w T^2)$. For the walls with lower velocity, the bound for ϵ is inevitably raised since such walls will dominate earlier.

Let us remember the simplest case, then examine the electroweak baryogenesis induced by the supersymmetry breaking defects. In the thin boundary limit, the final baryon to entropy ratio for ordinary electroweak baryogenesis becomes [8]

$$\frac{n_B}{s} \sim 0.2\alpha_W^2 (g^*)^{-1} \kappa \Delta\theta_{CP} \frac{1}{v_w} \left(\frac{m_l}{T}\right)^2 \frac{m_h}{T} \frac{\xi^L}{D_L} \tag{2.6}$$

where D_L is the diffusion constant for leptons, and ξ^L is the persistence length of the current in front of the bubble wall. Here we use m_l and m_h for the lepton and Higgs masses.

Let us consider the case where the defect has the thin phase boundary and the fat symmetry broken region, and that most of the baryon number is kept in the defect. [3] Then we should integrate n_B during the period of $T_c > T > T_{EW}$. The wall configuration is also different from the ordinary one. The Higgs vacuum expectation value in the broken phase is much larger, and $\Delta\theta_{CP}$ is not required to be small. One should also consider the volume factor, and the cancellation between the opposite boundary. To estimate the final baryon to entropy ratio, one should determine the wall profile in detail and then consider the evolution of the defect network in numerical methods, which is outside the scope of this paper.

We will also consider what happens when walls shrink or collapse at $T \leq T_{EW}$. When walls shrink, the inside region of the decaying bubble will be heated and the temperature in the inside can be higher than the outside. Then the sphaleron can be activated in the inside and produces the baryon asymmetry, while the baryon number violating processes are suppressed in the bulk of space. This may enhance the production of the baryon number even after the electroweak phase transition.

We should note that the field that condensate in the core is not necessarily the Higgs field, but any condensate carrying $SU(2)_L$ quantum numbers can contribute to the sphaleron energy and suppresses the baryon number breaking sphaleron interactions in the core region. If a condensate is carrying the baryon number, then there will be massless excitations of the Goldstone boson as well. We will discuss this topic later for strings and junctions.

We also note that the baryons produced by other mechanisms before the electroweak phase transition can survive the wash-out if they are trapped in the symmetry breaking defects. This may open up another possibility for baryogenesis.

String defects

Now let us consider a specific case for the cosmic string. Here we consider an example when the defect is a local string and the false vacuum in the core breaks color symmetry developing the squark vacuum expectation value. This assumption is natural, since the color breaking minimum is a natural feature of the supersymmetry breaking. Of

[3] Although the background changes gradually for fat defects, the electroweak phase transition occurs at the critical point and the phase boundary can be much thinner than the background defect.

course, one can introduce an additional defect sector which induces the required symmetry breaking.

In this case, baryon number is spontaneously broken inside the string, and the baryonic charge may be stored in the core of the string. Denoting the squarks as $\tilde{q}$, they carry a $U(1)$ baryonic global charge which is derived from the conserved current

$$J_B^\mu = \frac{i}{2}\sum_q q_B^q \left(\tilde{q}^\dagger \partial^\mu \tilde{q} - \tilde{q}\partial^\mu \tilde{q}^\dagger\right), \tag{2.7}$$

where q_B^q is the baryonic charge associated with any field $\tilde{q}$. Under the assumption of cylindrical symmetry, the baryonic charge per unit length Q_B along the z-axis will be given by $Q_B = \int d\theta dr\, r j_B(\theta, r)$ where j_B is the current per unit length along the same axis. This type of string is expected to generate the suitable baryon number asymmetry of the Universe, if some conditions are satisfied[14].

Junctions

By interpolating two degenerated vacua in separate regions of space, we obtain a domain wall. If we have three or more discrete vacua in separate regions of space, segments of domain walls can meet at a one-dimensional junction and there arises a domain wall junction. These junctions can have the structure which is very similar to the strings.

While the evolution of junctions are different from the strings and probably much more complicated to analyze, it is clear that they can be a candidate for the seeds for the baryon asymmetry in the Universe.

3 Toy model 2 (Extra dimension)

We also note that our mechanism can easily be generalized to include the brane models in which the hierarchy is explained by the mechanisms other than supersymmetry. When the hierarchy is determined by the typical length scales of the extra dimensions, there must be some mechanisms that ensure the stability of such scales. If the mechanism for the stability is affected by the defects on the brane or in the bulk, the defects may induce the displacement of the electroweak scale in the defect core or in the false vacuum, resulting in the same mechanism discussed above.

Here we examine an attractive model proposed by Goldberger and Wise[2] for giving the radion a potential energy to stabilize the length scale. They introduced a bulk scalar field with different VEV's, v_0 and v_1, on two branes. If the mass m of the scalar is small compared to the scale k which appears in the warp factor e^{-ky}, then it is possible to obtain the desired interbrane separation and one finds the relation $e^{-ky} \simeq (v_1/v_0)^{4k^2/m^2}$. They added to the model a scalar field Φ with the following bulk action

$$S_b = \frac{1}{2}\int d^4x \int_{-\pi}^{\pi} d\phi \sqrt{G}\left(G^{AB}\partial_A\Phi\partial_B\Phi - m^2\Phi^2\right), \tag{3.1}$$

where G_{AB} with $A, B = \mu, \phi$ is given by[17]

$$d^2s = e^{2kr_c|\phi|}\eta_{\mu\nu}dx^\mu dx^\nu - r_c^2 d\phi^2. \tag{3.2}$$

They also included interaction terms on the hidden and visible branes (at $\phi = 0$ and $\phi = \pi$ respectively) given by

$$S_h = -\int d^4x \sqrt{-g_h}\lambda_h\left(\Phi^2 - v_h^2\right)^2, \tag{3.3}$$

and

$$S_v = -\int d^4x \sqrt{-g_v}\lambda_v\left(\Phi^2 - v_v^2\right)^2, \tag{3.4}$$

where g_h and g_v are the determinants of the induced metric on the hidden and visible branes respectively. The terms on the branes cause Φ to develop a ϕ-dependent vacuum expectation value $\Phi(\phi)$ which is determined classically by solving the differential equation

$$\begin{aligned} 0 &= -\frac{1}{r_c^2}\partial_\phi\left(e^{-4\sigma}\partial_\phi\Phi\right) + m^2 e^{-4\sigma}\Phi + 4e^{-4\sigma}\lambda_v\Phi\left(\Phi^2 - v_v^2\right)\frac{\delta(\phi-\pi)}{r_c} \\ &\quad + 4e^{-4\sigma}\lambda_h\Phi\left(\Phi^2 - v_h^2\right)\frac{\delta(\phi)}{r_c}, \end{aligned} \tag{3.5}$$

where $\sigma(\phi) = kr_c|\phi|$. Away from the boundaries at $\phi = 0, \pi$, this equation has the general solution

$$\Phi(\phi) = e^{2\sigma}[Ae^{\nu\sigma} + Be^{-\nu\sigma}], \tag{3.6}$$

with $\nu = \sqrt{4 + m^2/k^2}$. Putting this solution back into the scalar field action and integrating over ϕ yields an effective four-dimensional potential for r_c. Then the unknown coefficients A and B are determined by imposing appropriate boundary conditions on the 3-branes. They considered the simplified case in which the parameters λ_h and λ_v are large, and supposing that $m/k \ll 1$, and neglecting the subleading powers of $\exp(-kr_c\phi)$, then obtained the potential as

$$V_\Phi(r_c) = k\epsilon v_h^2 + 4ke^{-4kr_c\phi}(v_v - v_h e^{-\epsilon k r_c \phi})^2 \left(1+\frac{\epsilon}{4}\right) - k\epsilon v_h e^{-(4+\epsilon)kr_c\phi}(2v_v - v_h e^{-\epsilon k r_c\phi}) \quad (3.7)$$

where terms of order ϵ^2 are neglected. If one ignores the terms proportional to ϵ, this potential has a minimum at

$$kr_c = \left(\frac{4}{\pi}\right)\frac{k^2}{m^2}\ln\left[\frac{v_h}{v_v}\right]. \quad (3.8)$$

With $\ln(v_h/v_v)$ of order unity, one only needs m^2/k^2 of order 1/10 to get $kr_c \sim 10$.

In this limit, it is energetically favorable to have $\Phi(0) = v_h$ and $\Phi(\pi) = v_v$. The configuration that has both VEVs of the same sign has lower energy than the one with alternating signs, and therefore corresponds to the ground state.

Then a question arises: *"What happens if the vacuum with alternating signs is also produced at an early stage of the Universe?"* Then from eq.(3.7), one can easily find that each term in the effective potential has the same positive sign and it looks like a runaway potential for such an unstable configuration. In our case, however, runaway will be stopped since there are neighboring true vacua surrounding the false vacuum. Although the estimation is rather crude, it should be true that the warp factor changes its value in this local region. The domain wall that interpolates the vacuum with $\Phi(\pi) = v_v$ and $\Phi(\pi) = -v_v$ at the visible brane (or possibly $\Phi(0) = v_h$ and $\Phi(0) = -v_h$ at the hidden brane) is nothing but the commonly known Z_2 domain wall with explicit breaking of Z_2 symmetry in the effective four dimensional theory.

For electroweak baryogenesis to be possible, as we have noted, one needs some specific region where Higgs vacuum expectation value $< H >$ is displaced from the equilibrium value. Here the difference of the warp factor is expected to induce the difference of the electroweak scale in the local region. The idea we have examined in the last section is that the electroweak scale is effectively raised along topological defects and symmetry breaking is induced in the local region. Baryon number is produced in the bulk of space, then kept in the topological defects. Now we consider the case where the electroweak symmetry breaking scale is suppressed in the false vacuum. Then sphaleron interactions are activated in this restricted area while they are suppressed in the bulk of space when $T < T_{EW}$. The motion of the defect network, in a similar way as the motion of bubble walls in the usual strongly first order phase transition scenario, will leave a net baryon number behind the moving surface and then the baryon asymmetry will be kept in the sphaleron-suppressed regions.

Here, the time when walls collapse should be important for this mechanism to work. They must collapse after the electroweak phase transition, but not later than nucleosynthesis. When the collapse is induced by the energy difference ϵ which is induced by the explicit breaking of Z_2 symmetry, one can add extra components on the boundary (or in the bulk) to adjust ϵ to a suitable value. Another mechanism is the biased domain wall, whose decaying process is determined by cosmology, and may (or may not) be adjusted to produce the suitable domain wall structure.

We should note that the radion stabilization is generally affected by the potentials on the brane and in the bulk[18]. In this respect, the defects in the bulk or on the brane can act to displace the radion even if no specific mechanism is implicated, and there is a chance for our mechanism to work in any models for radion stabilization.

It is also interesting that our mechanism for baryogenesis works below the electroweak phase transition.

4 Conclusions and Discussions

In this paper we have examined several possibilities for electroweak baryogenesis mediated by cosmological defects.

First, we analyzed the supersymmetric theories in which the hierarchy is produced by the soft breaking of supersymmetry. Although the magnitude of the baryon asymmetry depends on the profiles of the defects, the idea is general and can be applied to any models for supersymmetry. We also note that the baryons produced by other mechanisms before the electroweak phase transition can survive the wash-out if they are trapped in the symmetry breaking defects. This may open up another possibility for baryogenesis.

Next we considered an interesting aspect of the Goldberger-Wise mechanism for the stabilization of the radion in the RS model. If the false vacuum configuration is produced and then decays after the electroweak phase transition, a new mechanism for electroweak baryogenesis works at a lower temperature. We expect that this mechanism works in other models for extra dimensions in which the radion is stabilized by the configurations in the bulk or on the brane[19].

5 Acknowledgment

We wish to thank K.Shima for encouragement, and people in Tokyo University for kind hospitality.

References

[1] R.Brandenberger, A.C.Davis, M.Trodden, Phys.Lett.B335(1994)123; Phys.Rev.D53(1996)4257; Phys.Lett.B349(1995)131; Phys.Rev.D54(1996)6059.

[2] W.D.Goldberger, M.B.Wise,Phys.Rev.Lett. 83 (1999)4922.

[3] R.Barbieri, S.Ferrara and C.A.Savoy, Phys.Lett.119B(1982)343; A.H.Chamseddine, R.Arnowitt and P.Nath, Phys.Rev.Lett.49(1982)970; L.J.Hall, J.Lykken and S.Weinberg, Phys.Rev.D27(1982)2359.

[4] J.Polonyi, Budapest Report No.KFKI-93(1977).

[5] P.Niles,Phys.Lett.115B(1982)193; Nucl.Phys.B217(1983)366.

[6] L.O'Rafeartaigh,Nucl.Phys.B96(1975)331.

[7] P.John, M.G.Schmidt,hep-ph/0002050.

[8] A.Riotto and M.Trodden,Ann.Rev.Nucl.Part.Sci.49(1999)35.

[9] A.Vilenkin, Phys.Rev.D23(1981)852.

[10] J.A.Harvey, E.W.Kolb, D.B.Reiss and S.Wolfram, Nucl.Phys.B201(1982)16; T.Vachaspati and A.Vilenkin, Phys.Rev.D30(1984)2036.

[11] T.Matsuda,Phys.Lett.B436(1998)264;Phys.Lett.B486(2000)300.

[12] S.A.Abel, S.Sarker and P.L.White, Nucl.Phys.B454(1995)663 T.Han, D.Marfatia and Ren-Jie Zhang Phys.Rev.D61(2000)013007.

[13] J.A.Friedman, C.T.Hill and E.Watkins, Phys.Rev.D50(1992)1226;
A.Singh, Phys.Rev.D(1994)671;
A.M.Fuller and D.N.Schramm, Phys.Rev.D45(1992)2595;
A.Massarotti and J.M.Quashnock, Phys.Rev.D47(1993)3177;
S.Lola and G.G.Ross, Nucl.Phys.B406(1993)452.

[14] R.Brandenberger, A.Riotto,Phys.Lett.B445(1999)323.

[15] V.A.Rubakov, M.E.Shaposhnikov, Usp.Fiz.Nauk166(1996)493;
Phys.Usp.39(1996)461.

[16] J.R.Espinosa, hep-ph/9901310;
J.M.Cline, J.R.Espinosa, G.D.Moore, A.Riotto, Phys.Rev.D59(1999)065014

[17] L.Randall and R.Sundrum,Phys.Rev.Lett.83(1999)3370.

[18] B.Grinstein, D.R.Nolte, W.Skiba,hep-th/0012202

[19] M.A.Luty and R.Sundrum, Phys.Rev.D62(2000)035008; Z.Chacko and A.E.Nelson, Phys.Rev.D62(2000)085006;